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Fair Site and the Mark II Balloon Tether Winch

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Abstract

This paper discusses the Mark II Balloon Tether Winch which was developed for permanent installation at the Fair Site, White Sands Missile Range, Holloman AFB, New Mexico. This site will be operated by Detachment 1, AFCRL, Holloman AFB, New Mexico. Several unique features of the winch system and the Fair Site will be discussed.

The winch systems were designed to accommodate most known tethered balloon systems, with the ability to be expanded to future increases in balloon magnitude and altitude. Features are incorporated to take advantage of future developments in materials and physical construction of tether lines. Major winch components are arranged so that increased capacity stowage drums and more complex systems can be made with a minimum expense and alteration.

Visual aids will be employed to assist in presenting a general explanation of the Mark II Winch. The control system, main hydraulic system, capstan drive, and the stowage drum drive will be discussed. A "Servo Wind", level-wind system was developed to spool the tether line on the drum without gear adjustments when changing line sizes. A line clamp device with deceleration features is employed

to clamp and hold the moving tether cable with a minimum of shock on the line or tethered balloon. In general, the Mark II Winch is a deviation from the conventional approach to line pulling mechanism.

33.1 FAIR SITE

Increasing interest in the application of tethered balloons for research studies over the past decade has involved AFCRL's Aerospace Instrumentation Laboratory - a natural outgrowth of its free ballooning activities. Many times AFCRL Detachment 1, Balloon R & D Test Branch, located at Holloman Air Force Base, New Mexico, has been called upon to support research projects using a temporary tethered site near the Detachment 1 facility.

Nearly 200 tethered balloon flights of varying configurations have been made over the past few years. Notable were: (1) the tethered balloon platforms provided for NASA's Surveyor vehicle, (2) a tether system for the Circus Day balloon which attained an altitude of 12,000 feet MSL, (3) currently, three line tethered flights to 2,000 feet above ground for the Army's Project HOMINE and (4) evaluation tests for the Athena Project, Office of White Sands Missile Range.

As a result of the increase in tethered programs and the potential for extended capabilities, a permanent tethered balloon site was obviously needed. The site should: (1) be capable of routinely handling payloads of 500 pounds or less to altitudes of 10,000 feet above ground, (2) not be encumbered by other programs, (3) be in a restricted air space area to permit flight durations of hours to weeks and (4) the area should allow for equipment expansions to accommodate development tests and operations of tethered systems of much greater payload altitude capabilities. With this in mind, the Aerospace Instrumentation Laboratory has been constructing a permanent ground handling site located on the White Sand Missile Range, New Mexico. This site, now under construction, will be called the Fair Site.

This site is located in the northwest corner of a restricted area, R-5107-B, on the White Sands Missile Range. It is approximately 70 land miles from the Detachment 1, Balloon R & D Test Branch facilities located at Holloman AFB, New Mexico. Here, tethered balloons can be flown to unlimited altitudes with the only restrictions being range scheduling. Meteorological conditions have been investigated fully, and the climatology indicates a good year-round flight capability. The site has the advantage of a fully instrumented range to provide data essential in evaluating tethered balloon systems.

Position data for tethered balloon flights can be obtained using either FPS-16 radars or cinetheodolites or both. If radar is used, a position display can be set up at the Balloon Control Center or at some Range Control Station. Velocities, accelerations and balloon altitude data can be obtained from the cinetheodolites. Data reduction can be provided through WSMR. In addition to the cinetheodolites and radars, facilities for receiving F.M. telemetry are also available.

Range Accuracy:

(1) FPS-16 Radar (two radars available)

(a) Balloon at 10,000 ft. with transponder.
Max. error ± 15 yards in range.
Max. error ±0.3° azimuth and elevation.

(b) Balloon at 10,000 ft. with reflector.
Max. error ± 50 yards in range.
Max. error ± 0.3° azimuth and elevation.

(2) Cinetheodolite

(a) Balloon at 10,000 ft.
Slant range error of ± 6 ft. in position.

Figure 33.1 depicts the site layout. Two main winch systems are shown, each of which is used in conjunction with a common ground zero. The ground-zero

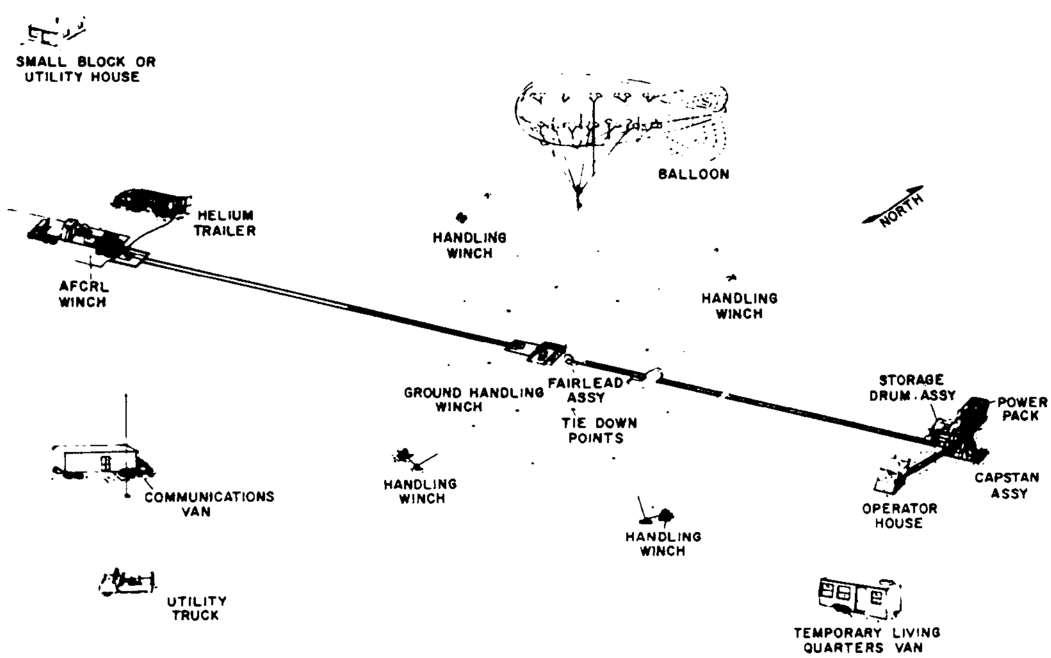

Figure 33.1. Fair Site Showing Typical Tether Operations with the Mark II Winch on the Right and the AFCRL Winch on the Trailer at Left

position incorporates both a 20-inch and 30-inch diameter sheave. Between the two sheaves is located a ground handling winch capable of handling 30,000 lbs at speeds of approximately 20 feet per minute. The purpose of this winch is to facilitate the ground handling of the balloon and payload. Located at ground zero are inner and outer anchor points. The inner anchor points are used to secure a cable system forming a pyramid used to moor barrage balloons. It is possible to moor a barrage balloon on this pyramid in winds up to 25-30 knots. In winds in excess of 30 knots, the balloon will be moored on a heavy steel cable approximately 100 feet above the ground.

The outer anchor points are used in the initial handling of the balloon. During balloon inflation, it is important that the nose of the balloon heads directly into the wind. Placement of the outer anchor points have been made to permit ten different directions. These directions will permit alignment of the balloon within 18° of any given wind direction. The ground handling winches have been positioned in such a manner that only four will be required to operate the system.

This site has been designed to handle a wide variety of tethered balloon systems. The AFCRL mobile winch on the left is capable of loads up to 4,000 pounds at speeds of approximately 300 feet per minute. The winch is capable of speeds up to 1,000 feet per minute at reduced loads in the range of a 1,000 pounds. The winch has been designed to handle cable sizes of 1/16-inch diameter to 3/8-inch diameter. The unique level wind provided by Otis Engineering Corporation can accommodate cable sizes from 1/8-inch to 3/8-inch diameter without changing drums or level wind systems. The cable is stowed on a drum at tensions between 150 to 300 pounds coming directly off the traction drive. The instrument pad is used to measure the cable speed, footage and load at ground zero. Reading at sheave is provided with approximately 1 percent accuracy of the full scale readings. The AFCRL winch positioned in Figure 33.1 illustrates the use of a mobile winch in a permanent site configuration. The winch can also be used remotely where the balloon can be flown directly from the winch at any location.

Depicted on the right is the Mark II Winch. This winch will be permanently located at the Fair Site and has been specifically designed for use at this facility. The winch is capable of controlled speeds up to 1,000 feet per minute and loads of 30,000 pounds. Mr. Turner of Otis Engineering Corporation will discuss the operational characteristics of the Mark II Winch with you in greater detail.

33.2 MARK II BALLOON TETHER WINCH

Otis Engineering Corporation, a Halliburton Company, was awarded the contract to develop and manufacture the Mark II Balloon Tether Winch in early 1969.

The performance specifications established the following requirements:

(1) Line pull capabilities of 30,000 pounds maximum at a maximum speed of 200 feet per minute.

(2) Line pull capabilities of 6,000 pounds at line speeds of 1,000 feet per minute.

(3) Variable speed control in each of the above modes.

(4) Fail-safe brake system.

(5) Interchangeable sheave and capstan shoes.

(6) Drum capacity to 30,000 feet of 1/2-inch diameter line.

(7) The capability of accommodating line sizes from 3/8-inch through 3/4-inch diameter.

(8) Level wind system capable of storing these line sizes uniformly on the stowage drum and adjustable for 3/8-inch through 3/4-inch with 1/16-inch variation in diameter.

(9) Instrumentation consists of a line load measuring device, line footage counting device, line speed and direction measuring device.

(10) Other instruments included those items necessary to monitor the operation of the power source and the hydraulic drive system.

The design was, then, predicated around five major components: (1) the main capstan pulling unit, (2) the main power source, (3) the stowage drum, (4) control house, and (5) the ground-zero fairlead sheaves and ground handling winch.

The main capstan assembly (Figure 33.2) consists of two 30-inch pitch diameter multi-grooved sheaves with interchangeable shoes attached to the outer periphery of the main sheave wheels. The interchangeable shoes are coated with polyurethane to provide a resilient surface for the line to bear on. The shoes are provided with six grooves to obtain the necessary friction to provide line pulls up to 30,000 pounds without the line slipping in the grooves.

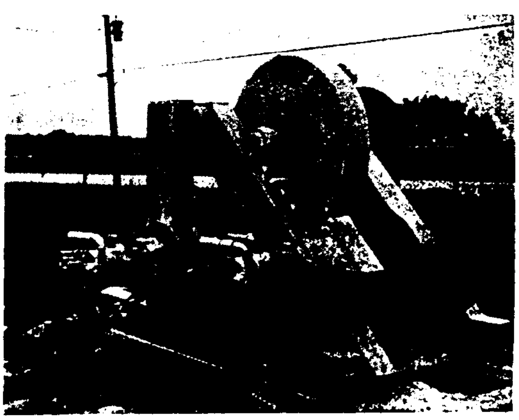

Figure 33.2. Main Capstan Drive Showing the Hydraulic Input Side with Gear Boxes

The capstan unit contains a weight-indicating sheave which provides a change in direction of the high-load line leaving the capstan. This change in direction of the high-load line leaving the capstan provides a point where the resultant forces can be utilized to measure the tension in the line. The exit point from the capstan measuring sheave to the fairlead sheave is made with no reverse bends in the line. The weight-measuring sheave is positioned in the near center of a large yoke and is free to rotate about its center axle. The yoke is pivoted at the lower end; line tension at the sheave produces a moment, exerting a force on the load cell at the upper end of the yoke. The hydraulic load-cell pressure, resulting from the force applied, is monitored by one of two pressure gauges. One is calibrated to read 0 to 30,000 pounds and one is calibrated to read 0 to 10,000 pounds. The direct-reading gauges are calibrated from the resultant of the line tension and the included angle.

The line speed and counting device is also attached to the main capstan and measures the speed in feet per minute of the line when inhauling or outhauling. It also measures the length of line payed out or pulled in.

The capstan is provided with a two-phase input power system. The high-speed phase is accomplished through an axial piston hydraulic motor, which supplies torque through a planetary-gear transmission directly into the lower capstan shaft. The low-speed, high-torque phase is provided by an axial piston hydraulic motor, applying torque directly into a planetary-gear transmission and auxiliary drive shaft. The auxiliary shaft applies torque through an air clutch to the upper capstan shaft through a chain reduction, which is sized to provide necessary torque for line pulls up to 30,000 pounds. The sprocket pinion from the auxiliary shaft is attached to the air brake, providing the fail-safe brake system.

The power unit, located adjacent to the main capstan drive opposite the control house, utilizes an 8V71 series diesel engine with a horsepower capability of 280 at 2100 rpm (Figure 33.3). The stationary power unit is provided with its own cooling system and electric starting system.

The engine is used to power an 11-cubic-inch, axial piston, pressure compensated, variable volume, hudraulic pump coupled to the flywheel. A 5.77-cubic-inch, variable volume, pressure compensated, vane type hydraulic pump is direct-coupled to the engine cam shaft drive. The engine is also equipped with an air compressor, an air storage tank, and a 300-gallon fuel tank mounted on a separate skid adjacent to the engine.

All engine controls and instruments, including the air throttle control, are located in the operator's control house.

The third, and an important part of the Mark II balloon-tether winch is the stowage drum assembly (Figure 33.4). The frame of the assembly is sized to accommodate stowage drums with capacities of 30,000 feet of 1/2-inch tether cable. The design is such that the drums are interchangeable, and can be manufactured to accommodate various line lengths and sizes. The winch is provided with two drums – one for 20,000 feet of 5/8-inch Nolaro cable and one for 12,000 feet of 3/8-inch steel cable.

Figure 33.3. Mark II Balloon Tether Winch Showing Control House, Stowage Drum, Main Capstan Drive and Power Unit

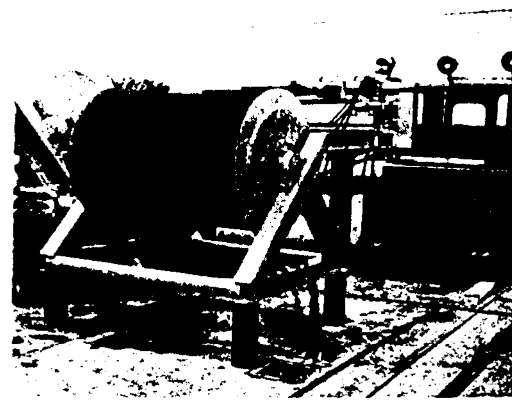

Figure 33.4. 3/8" Stowage Drum

The power to rotate the drum is provided by a high-torque gear motor and chain drive to the drum shaft. The hydraulic fluid for the gear motor is furnished by the vane-type, pressure-compensated pump, mounted on the engine cam-shaft drive. This pressure can be regulated to produce line tensions from 200 to 600 pounds.

The design is such that the stowage drum is always rotating in a direction to wind the line on the drum. In the outhauling phase, the capstan must overcome this small tension and rotate the drum against the power applied to pull the line from the drum. This prevents overrunning of the drum when stopped.

In front of the stowage drum is the level wind assembly. The large 30-inch sheave traverses along its guide system, parallel to the face of the drum. Power to traverse this sheave is furnished by a hydraulic Tol-O-Matic cylinder, located just beneath the sheave support members. The direction of movement of the Tol-O-Matic cylinder is controlled by a servo valve attached to the sensing arm, located adjacent and tangent to the level wind sheave. The servo valve positions the level wind assembly by measuring the angle between the drum axis and the cable being spooled on the drum. As the line falls next to its adjacent wrap, a slight angle is formed between the line and the drum axis. This angle is sensed by the sensing arm, actuating the servo valve, directing the fluid to the side of the cylinder necessary to move the sheave, providing a near perpendicular angle between the drum and the line.

The nerve center of the Mark II balloon tether winch is the operator's control house, (Figure 33.5). All winch-operating functions are performed from the control console located inside the house. The main speed control and direction

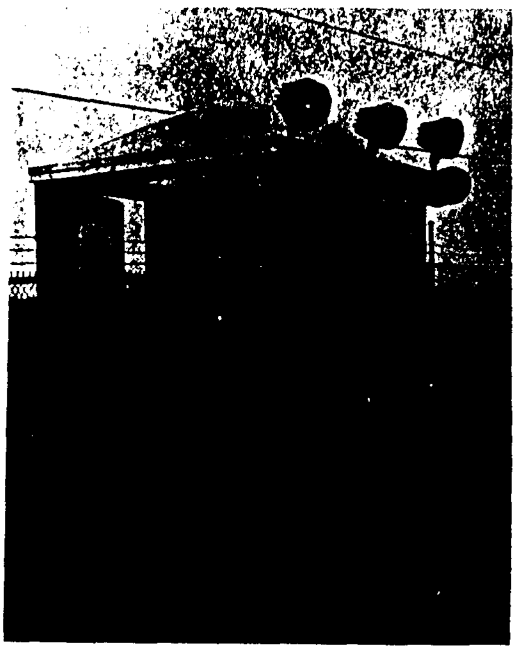

Figure 33. 5. Control House

Figure 33. 6. Partial Instrumentation Inside Control House Showing Control Handle, Weight Indicator Gauge, Counter and Engine Control

handle is located near the center of the panel (Figure 33. 6), and is of a cam design, having a 15:1 ratio at the starting mode, reducing the ratio to 1:1 in the extended positions. This type control offers very sensitive operation in the starting phases.

The high- and low-drive phase selector is also located on the control console and is a hydraulic valve used to actuate pilots on the main control valves mounted on the capstan skid. Various engine instruments are located on the left side of the console, along with the start and stop buttons. The tension-monitoring gauge and the line counters are located near the geometric center of the panel, so that the operator has both gauges in his field of vision. The remote line-pull adjustment handle is located on this panel and is graduated to indicate the line pulls desired within certain limits. Finite line-tension adjustments are made with the winch operating.

The high-tension and low-tension alarm horn is mounted on the house and has a back-up system of lights on the panel. The operator can turn off the alarm; however, the light remains on until the cause is corrected. Another control light is provided to indicate when system pressure has reached the setting of the pressure compensator. This light indicates the maximum line pull is being obtained for the pressure range established.

There are two hydraulic systems on the Mark II balloon tether winch (Figure 33. 7). The main system provides power for the capstan drives and is a closed-loop hydrostatic transmission. The pump is a variable-volume, pressure-

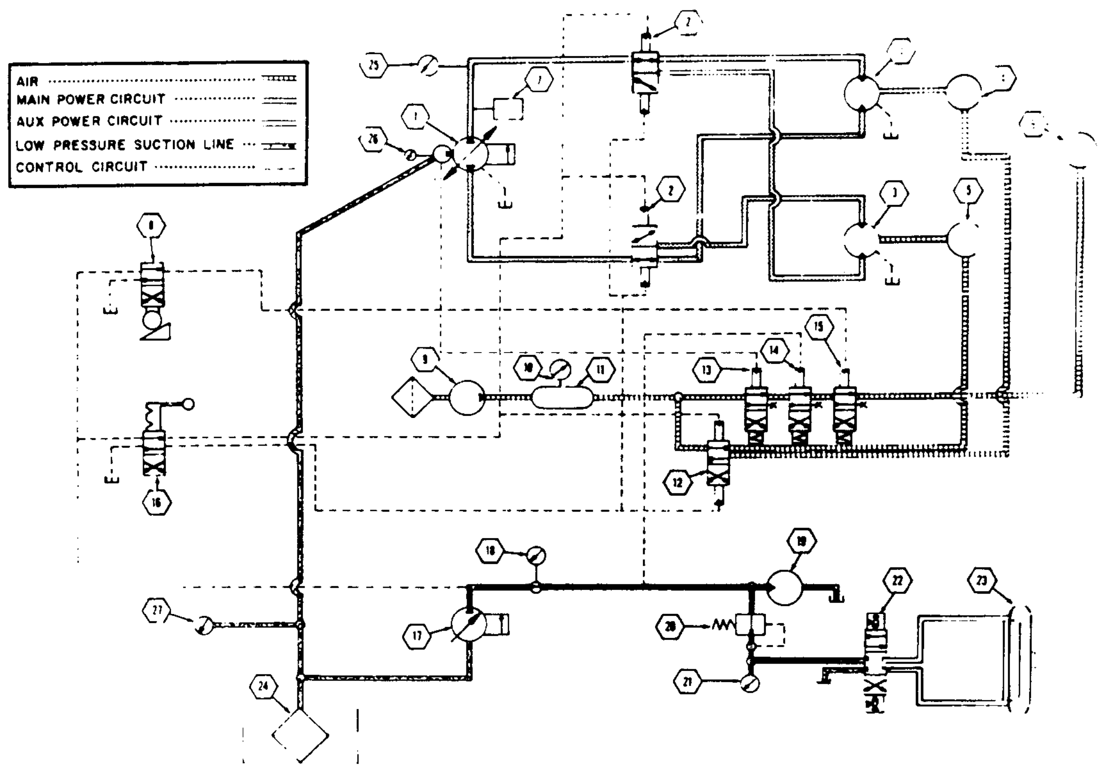

Figure 33.7. Hydraulic Circuit

compensated, axial-piston type. The pump is capable of delivering fluid in both directions. The fluid from the pump is directed to the desired motor through a pilot-operated, selector valve. Two of these valves are provided — one for the high-speed drive and one for the low-speed drive. The actuator control valve utilized to position the selector valve also actuates an air valve, engaging the air clutch for that particular drive phase.

The other hydraulic system powers the drum drive and the level-wind system. The cam shaft drives a vane type, pressure-compensated pump, supplying fluid directly to the drum drive motor. This system is automatic and requires no operator control. A portion of the secondary-system fluid is used to power the level wind system. The secondary hydraulic system also furnishes pilot pressure for manipulating the clutch and brake air valves. The air brake control is integrated with the speed and direction control handle, such that when the handle is in the center, or stop position, the brake is automatically applied. The other brake valves are utilized as fail-safe actuators in the event of failure in the secondary or primary hydraulic system.

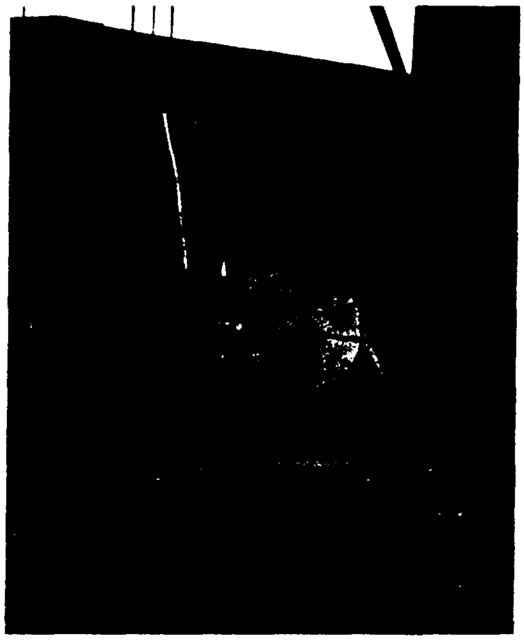

Figure 33. 8. Fairlead Assembly

The ground handling equipment provided with the Mark II Balloon Tether Winch is a 30, 000-pound fairlead sheave assembly (Figure 33. 8), designed to allow the line to leave the sheave in a 360° angle in the horizontal plane and 0° to 90° in the vertical plane. A small ground-handling winch, capable of exerting pulls to 30, 000 pounds, and its electric hydraulic power unit are located in the cellar, adjacent to the fairlead sheave assembly.

In the line trough, near the ground zero point, a line clamping device is located to stop and hold the line in the event of an emergency. This clamping device is actuated by a control in the operator's control house. The line clamp is supported by a lineal decelerating shock absorber system to absorb the load on the line, reducing its speed gradually to prevent shock loading on the cable.

33.3 SUMMARY

The Mark II Balloon Tether Winch is designed and manufactured as a research tool. Interchangeability of capstan and sheave shoes, as well as the stowage drums, permits operations to use different kinds and sizes of tether lines. The ability to mold other resilient materials to the shoes expands the scope of this winch to tether cables not yet developed. The arrangement of components on site will allow other stowage drums to be added along either side of the cable trough. These additional stowage capabilities can be accomplished with a minimum expenditure of time and monies. The flexibility of this system and its adaptability to future concepts will prolong the useful life of this winch system.